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United States Railroad
Administration

The economical use of
railroad fuel

Washington

1919

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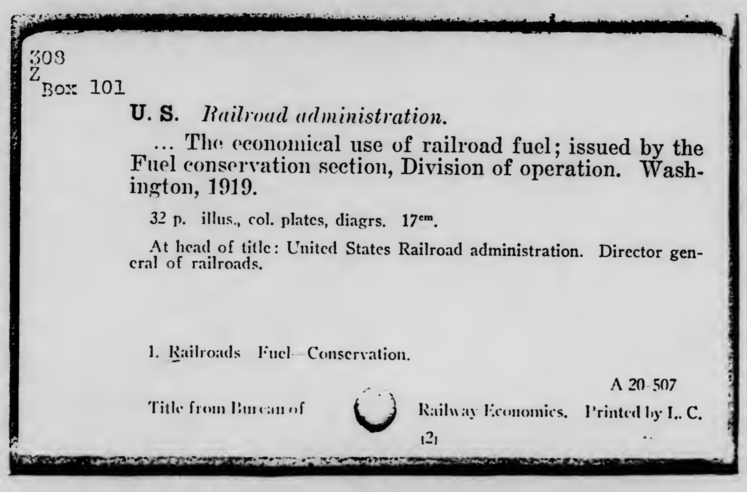

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The Economical Use of Railroad Fuel

UNITED STATES RAILROAD ADMINISTRATION
Director General of Railroads

The Economical Use of Railroad Fuel

Issued by the
Fuel Conservation Section
Division of Operation

1918

WASHINGTON
1919

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FOREWORD.

In June, 1918, the Fuel Conservation Section, Division o Operation, United States Railroad Administration, issued Publication No. 1, "Saving Railroad Fuel," a little pamphlet of 12 pages, which contained 81 specific suggestions to railroad operating officials, to roundhouse officials, to locomotive engineers and to locomotive firemen and hostlers.

The instructions issued to enginehouse officials and enginemen are of that concise, practical nature that they will bear repetition, and same have been added to this publication, which has been prepared and distributed for the purpose of again presenting to enginehouse officials and enginemen the vital importance of each and every man doing everything in his power to conserve railroad fuel.

This pamphlet is submitted for your study and guidance. It contains only that measure of instruction and information which practical enginehouse officials and enginemen have developed out of their own experience. If every employee will make a conscientious effort to follow the advice contained herein, such will result in saving several million dollars' worth of railroad fuel annually.

Fuel Conservation Section,
Division of Operation,
United States Railroad Administration

Washington, D. C., *November 30, 1919.*

PREFACE.

A railroad can be likened to a manufacturing concern—it manufactures and sells transportation. When the cost of producing a manufactured article runs somewhat below its selling price, the difference represents profit; if the cost of production exceeds the selling price, then this difference becomes a loss. There are two ways in which a business may attain large proportions, either by manufacturing and selling a reasonable number of items at a relatively high unit cost—for example, automobiles, thrashing machines, wagons, etc.—or by manufacturing and selling many millions of small items at a small price.

The railroads are in the last-mentioned class; they produce and sell millions of freight ton miles and passenger miles, receiving a very small sum for each item or unit of service sold. Fuel, which represents the second greatest item of operating cost, is something that is used by the men through whose hands it last passes in small units. Coal is handled by the scoopful, weighing 15 pounds, with about 133 scoopfuls to a ton.

Fuel oil is used by the gallon, which weighs 7.5 pounds. A scoopful of coal and a gallon of oil cost about the same at the present time, 3 cents. One scoopful of coal saved from each ton, equal to three-fourths of 1 per cent, with an equivalent saving in fuel oil, would represent an annual saving to the taxpayers of four million dollars. Reference is made to the taxpayers for the reason that in this country the railroads are so generally used by all the people, and the return in profit to the owners has been so small as to justify the statement that any saving made will accrue to the taxpayers or citizens generally.

While material savings have been effected in the past year, the fuel cost on all railroads is yet too high, and it is with the idea of bringing certain essentials to your attention that this book is handed to you. If the instructions in the book are followed by roundhouse men and enginemen, a further material saving can be effected which will reflect to the credit of those doing the actual work.

GENERAL INSTRUCTIONS.

HEAT AND POWER.

Fuel is burned in the locomotive firebox to produce heat. This heat in turn is imparted to the water in the boiler and generates steam. Steam is the vehicle through which heat acts in performing work. In other words, it is from the heat in the steam and not from the steam itself that we get power; therefore any loss of heat either before or after it is imparted to the water to make steam, or any loss of steam either directly or indirectly, is an absolute loss or waste of fuel.

To show how little of the heat in the fuel is actually converted into effective work at the drawbar of the locomotive, your attention is directed to figure 1, which shows that 52 per cent is in the exhaust steam which is used in creating draft, 1 per cent to overcome friction, 5 per cent is lost in radiation, 6 per cent to operate auxiliary devices, 14 per cent in unabsorbed heat in gases passing from the stack, 4 per cent in unburned gases and soot, 8 per cent in sparks thrown from the stack, and 4 per cent in coal falling into the ashpan, until finally we have but 6 per cent of the total heat or power in the fuel actually utilized in pulling cars. However, in this figure we are assuming the locomotive and boiler are in good condition; if, however, the boiler is in such condition as to partially obstruct or prevent the heat transference from the fuel to the water, or the machinery is in such shape that the full power in the steam is not obtained, you can readily see that even less than 6 per cent of the work in the fuel is really exerted in an earning way as drawbar pull. When we further consider the losses due to unskillful engine handling or to unskillful or indifferent firing, it is fair to assume that not over 5 per cent of the power in the fuel is actually converted into effective work in the average locomotive. (See fig. 1, p. 8.)

Draft in a locomotive firebox is the result of reducing the air pressure above the fuel bed to a point below the pressure underneath; therefore this draft is not a pulling proposition or something reaching down the stack and pulling the heat into the flues, but is a job of pushing, the higher air pressure under the grates pushing its way through the grate openings and fuel bed and in this way furnishing the oxygen necessary for combustion.

As the pressure underneath the grate is limited to that of the atmosphere, it follows that the first requirement for a good steaming locomotive is to have enough free air opening into the ashpan so that there will at all times be full atmospheric pressure under the grates. The amount of air opening necessary should always equal at least 14 per cent of the grate area. More air opening is still better.

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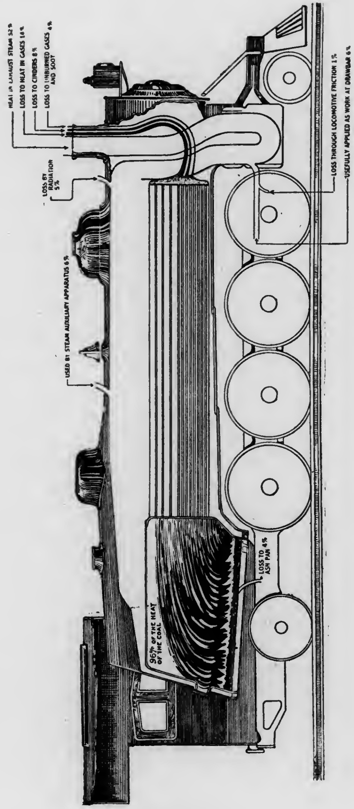

HEAT IN EXHAUST STEAM 52%
LOSS TO HEAT IN GASES 14%
LOSS TO CINDERS 8%
LOSS TO UNBURNED GASES 4%
AND SOOT
LOSS BY RADIATION 5%
USED BY STEAM AUXILIARY APPARATUS 6%
LOSS THROUGH LOCOMOTIVE FRICTION 1%
USEFULLY APPLIED AS WORK AT DRAWBAR 6%
LOSS TO ASH PAN 4%
96% OF THE HEAT OF THE COAL

Fig. 1.—Heat distribution in the locomotive

Having the necessary air in the ashpan, the next thing is to get it through the grates. As it takes about 300 cubic feet of air to furnish enough oxygen to burn 1 pound of coal (150 cubic feet is the theoretical amount, but in locomotive practice we find it necessary to admit about twice as much), and as the locomotive will burn from 80 to 120 pounds of coal per square foot of grate surface per hour—depending, of course, on how the engine is worked—it follows that the air openings through the grates must be of sufficient capacity to accommodate the volume of air required. Tests have shown that on the average locomotive burning bituminous coal the air openings through the grates should be equal to at least 40 per cent of the total area. For locomotives burning lignite coal, one-half of this, or 20 per cent, is enough.

While locomotives will steam with less than the above-mentioned air openings into ashpan and through grates, it is always at the expense of locomotive efficiency, as in order to obtain the amount of air necessary for combustion through restricted openings the velocity of the air currents must be increased, and this can only be brought about by decreasing the nozzle. A small nozzle always means increased back pressure, increased fuel consumption, and decreased engine efficiency. You can therefore see that the starting point for developing a good steaming efficient locomotive is at the ashpan and grates and not at the front end.

We now have the air under the fire trying to push its way through the fuel bed against the lesser pressure above the fire, but we want to find out how the air pressure above the fire is reduced below the pressure of the atmosphere, and this brings us to the front-end draft appliances.

These consist in the modern coal-burning locomotives of the stack, the exhaust nozzle, the petticoat or lift pipe, the diaphragm and draft plate, and the blower.

Exhaust steam from the nozzle or live steam from the blower passing up through the stack creates a partial vacuum in the front end. As the front end is air-tight, or should be at least, this partial vacuum can be filled from but one source, namely, the air in the flues and firebox, which prior to the engine exhausting or the blower being opened was practically at the same pressure as that in the front end and in the ashpan. Now as the air in the flues and firebox rushes into the front end to fill the partial vacuum created there, the air in the ashpan tries to force its way through the fire to replace it. This action of the air pressures trying to maintain a balance is what we term draft, and it only requires a difference of from 1⅓ to 2⅔ ounces of pressure above and below the fire to produce this draft, and this difference can be obtained by lowering the front-end pressure 8 or 10 ounces.

As shown above, the draft is produced by the steam escaping from the exhaust nozzle or the blower; therefore it follows that strictly speaking the only draft appliances necessary would be the stack and nozzle when the engine is working, and the stack and blower when the engine is shut off, drifting, or standing.

THE DIAPHRAGM AND DRAFT PLATE.

Air or gas currents, etc., do not always travel along straight lines but usually move in curves and along the line of least resistance; consequently, without some means of controlling the path of the gases there would be an uneven distribution of the draft over the grate area, and some of the flues would be doing more work than others. The draft plate and diaphragm are therefore put in to control the flow of gases through the flues and to distribute the draft over the grate surface as desired.

The draft plate has, however, another function, namely, to give direction to the gases in their passage from the flues to the stack, and in doing this, to aid in keeping the front end clear of cinders.

We can thus see that in so far as actually creating draft is concerned the draft plate is not a compelling factor, it simply serves to distribute the draft and to assist in keeping the front end clean. However, while the draft plate does not create draft, it is frequently so adjusted as to obstruct it, and in this way becomes a hindrance to the free steaming of a locomotive instead of a help.

The draft plate should always be set so that the opening between the plate and smoke arch is equal to 68 per cent of the total flue area. If the front end should show a tendency to fill up with cinders when the plate is raised, change the angle of the plate by drawing the bottom further back so it will stand nearly vertical. Furthermore, if the draft plate is too close to the front flue sheet the flow of the gases is so restricted as to cause the locomotive to be what is termed "hot at the door"; consequently it follows that carrying the draft plate as high as possible not only decreases the work of the fireman but also makes his work more comfortable. As it has been shown that the draft plate has but two functions, why change it after it has once been properly adjusted?

All front-end appliances should be maintained according to the blue-print standards as furnished by the mechanical department, keeping them in first-class repair and adjustment. Records should be kept of front-end adjustments so that when the locomotive is reported not steaming the foreman or man in charge of front ends will be able to tell whether some one has changed the size of the nozzle or any other adjustable parts, or whether the defect is in the locomotive. If the setting is on record and the locomotive has steamed for months, or years possibly, and is reported "not steaming," no changes should be made in the front end, but the real trouble should be found and corrected. If such practice is followed, front ends can be set standard and so maintained.

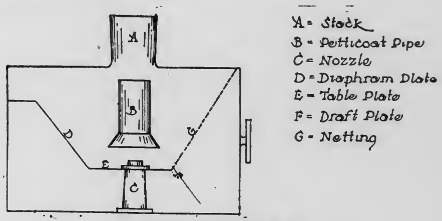


Fig. 2.—Standard front end.

THE PETTICOAT PIPE.

In the modern locomotive the only function of the petticoat pipe is to increase the stack length; therefore it should fit tight into the base of the stack and be made nonadjustable, that is, it should simply be a stack extension.

REDUCING THE NOZZLE TO MAKE A LOCOMOTIVE STEAM.

This is a standard remedy with the average roundhouse man, and is frequently used to cure all ills the locomotive is heir to. Reducing the nozzle should be the last resort, as it not only reduces the efficiency of the locomotive, but materially increases the coal and water consumption as well as the work of the engineman.

Changes in the physical characteristics of the fuel or climatic conditions make it necessary at times to increase the draft, but instead of bushing the nozzle better results can be obtained by applying a rectangular or dumb-bell shaped tip of the same area, or better yet, bore the tip out ¼ inch larger, then apply a ⅜-inch round bridge, spot welded at each end to make it stay in place.

The indicator diagrams on page 13 illustrate clearly the difference in back pressure at various speeds and cut-off with bushed and bridged nozzles. They also show the necessity of maintaining nozzles at the greatest possible diameter consistent with good steaming, and in this connection it might be well to call attention to this particular feature on yard locomotives engaged in short switching. Locomotives assigned to this work should have nozzle tips substantially as large as the opening in the nozzle pot. Yard locomotives do not require a sharp nozzle blast to make steam, and a large exhaust opening will not only materially reduce the fuel consumption but will make the work of the engine crew much more comfortable.

While bushing a nozzle will make a locomotive steam by lengthening the exhaust jet and increasing its velocity, yet what is gained in freer steaming is invariably lost in engine efficiency.

To illustrate this, refer to cards 2, 8, and 4, figure 3, which show the back pressure at 19 miles per hour with lever in twelfth notch, equal to 23½ pounds with a 5¼-inch open nozzle, the back pressure amounting to more than 26 per cent of the total horsepower developed, or to put it another way, more than one-fourth of the total power developed by the engine was lost in back pressure.

Refer now to card No. 8, taken at the same speed and cut-off. In this card the nozzle had been bored to 5½ inches, then a ⅜-inch bridge applied, bringing the area back to the equivalent of a 5¼-inch-diameter open nozzle. The card now shows, however, that even though a greater throttle opening was used and the steam pressure was higher, the back pressure was but 20½ pounds, as against 23½ pounds for the 5¼-inch open nozzle, a drop of 3 pounds in back pressure, or 5 per cent of the total horsepower developed. This suggests that the bridged nozzle offers less obstruction to the passage of steam than a nozzle bushed to the same area.

Turn now to card No. 4, where the nozzle was further increased to the equivalent of a 5½-inch open nozzle. As can be seen under the same running conditions, the back pressure has now been reduced to an average of 16½ pounds, or 15.62 per cent of the total horsepower developed, at the same time decreasing the fuel consumption 17 per cent.

It can thus be seen that one of the first considerations in fuel economy is the adoption of a standard setting in so far as draft plate, etc., is concerned, and in maintaining this standard, leaving the only variable the nozzle, and this should be bridged or bushed only when through changes in the physical characteristics of the fuel a sharper blast is necessary. Nozzles should not be reduced for any reason, however, except on the authority of some responsible officer, and not then until after thorough tests it has been shown that it is necessary, and that from a fuel point of view the locomotive is in good condition.

LOCOMOTIVE EFFICIENCY.

A locomotive may be able to handle its stated rating and yet be far from an efficient locomotive under the meaning of the term as applied in this book.

By an efficient locomotive we mean one that will handle its stated rating over a given district in the shortest time on a minimum quantity of fuel.

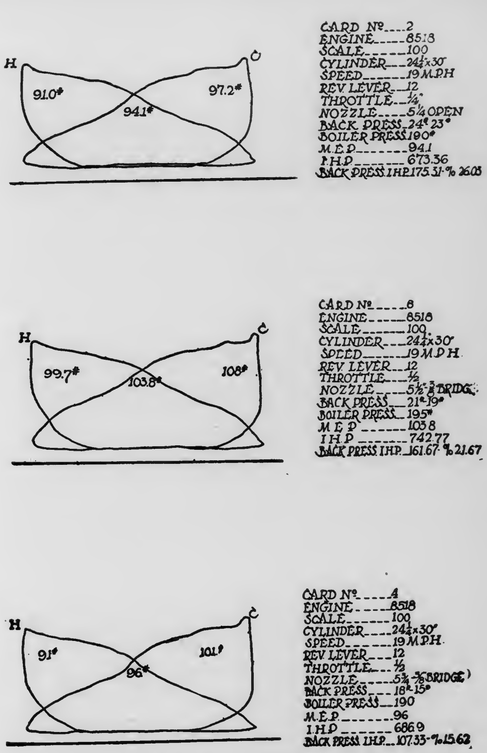


Fig. 3.—Indicator diagrams showing effect of back pressure.

Therefore, when we say a locomotive is 85 per cent efficient, or that its efficiency is reduced 15 per cent, we mean one that will require 15 per cent more time to make the same distance with the same tonnage as one that is 100 per cent efficient, or else that it will consume 15 per cent more fuel in doing the same work.

As a rule, poor time and excessive fuel consumption go hand in hand; therefore you can see that it behooves the enginemen to report everything that tends to decrease the efficiency of the locomotive, as the inefficient machine always means more and harder work for the engine crew.

DRAFT INEFFICIENCY.

Under this head would come anything that in any manner interfered with or reduced the draft. The worst offender in this direction is the front-end air leak, especially in superheated steam locomotives with steam pipes extending through the smoke arch. As a rule, in order to permit of their easy application and removal, the hole through the arch is cut large enough to accommodate the flange of the pipe. This opening is then partially closed by means of a split collar or bushing. In practically all of the locomotives built prior to 1918 this collar or bushing still left an opening around each pipe equal to a round hole 5¾ inches in diameter; consequently, when the exhaust creates a partial vacuum in the front end, some air moving along the line of least resistance will be drawn in through these openings instead of through the fuel bed, thereby decreasing the draft by that amount, making it necessary to reduce the nozzle in order to maintain the necessary vacuum. Tests have proven that sealing these openings permitted an increase of from ¼ inch to ⅜ inch in the diameter of the nozzle, resulting in a decrease of from 14 to 21 per cent in fuel with a corresponding increase in engine efficiency, at the same time very materially improving the locomotive's steaming qualities.

Another draft inefficiency found in superheated steam locomotives is the superheater damper. This should always be set at an angle of 60 degrees when open, the top of the damper leaning back; if set vertical it obstructs the draft through the bottom flues.

Among other draft inefficiencies can be mentioned steam leaks in front end either at steam pipe or nozzle joints or at the connections between the superheater units and header. Any steam thus escaping into the front end tends to fill the vacuum being created by the exhaust jet and so reduces the draft. While the unit joints may leak quite a little without affecting the steaming of the locomotive materially, these leaks nevertheless can waste considerable steam, and in this way waste fuel.

HEAT TRANSFERENCE.

The transfer of heat from the burning fuel to the water in the boiler is effected by the heat penetrating the iron and being absorbed by the water. Anything that offers resistance to this heat transfer results in a fuel loss as well as in a poor steaming locomotive. One of the most effective nonconductors of heat is soot; therefore the accumulated soot should be blown out of the flues each trip. It should not be necessary to say that all flues clogged with cinders should be thoroughly bored out, although all do not apparently realize to what extent stopped-up flues will affect the coal pile. Some tests recently conducted show that with one-half of the large smoke tubes stopped up, the performance of a superheated steam locomotive was reduced to practically that of a saturated locomotive, and the fuel consumption was increased 24 per cent; a lesser number of these tubes stopped up affected the fuel consumption proportionately. Other tests proved that with 100 small tubes stopped up and the grate openings partially obstructed with clinkers the fuel consumption was increased 47 per cent. This shows that cleaning flues, grates, etc., should receive the same careful attention accorded any other work.

SCALE ON FLUES AND FIREBOX SHEETS.

Tests have shown that a deposit of scale ⅛ inch in thickness resulted in a fuel loss of 15.6 per cent. While the roundhouse foreman can not entirely prevent the formation of scale on flues and firebox sheets, he can, however, help reduce it by careful, conscientious boiler washing.

STEAM LOSSES.

Under this head we should consider the losses due to defective valves and valve seats in slide-valve engines and valve rings and bushings in superheated steam locomotives, as well as the losses due to defective cylinder packing rings in either or both. Some of these defects are at times allowed to run for several trips uncorrected, especially in superheated steam locomotives due to the fact that the leak is often of such a nature as not to cause a very loud blow except at full stroke; if, however, the escaping steam were measured, the amount of steam lost would often prove surprising. Therefore it has been found a good plan on many railroads to make a regular inspection of valve rings and bushings, as well as cylinder packing rings at stated periods.

LOSSES DUE TO IMPROPER STEAM DISTRIBUTION.

Among roundhouse men it is a generally accepted opinion that valves but slightly out of adjustment make no material difference in so far as steam consumption is concerned, they failing to realize the engineer will invariably work an engine at a cut-off at which the engine sounds most nearly square. This will always be at a point of cut-off longer than would be necessary to handle the train and make time were the valves in perfect adjustment; this results in the use of more steam than would otherwise be required, and each additional cubic foot of steam so used means a corresponding loss of fuel and that much extra work for the fireman.

In order to determine how serious valve losses really were, tests were recently conducted to determine this feature, with the following results: On a locomotive handled by the same crew over the same division, pulling the same train day after day, the valve motion was distorted so that there was a difference of 5 inches in cut-off on one side only, in what would normally have been an 8-inch cut-off, resulting in a fuel loss of 18.3 per cent; another change of 2 inches in cut-off at 7 inches resulted in a loss of 14.6 per cent, and yet the gear was not thrown out enough to make the locomotive sound very lame or prevent it making the time. This suggests that the engineer should always report all cases where the locomotive does not sound square and that the roundhouse man should make the proper adjustment as soon as reported. Lost motion will gradually develop in any valve gear, and lost motion will throw valves out of adjustment and so affect the steam distribution, steam consumption, and general locomotive efficiency. In fact, the effect on locomotive efficiency of improper valve adjustment reaches much further than the coal pile, although the fuel consumption is the most convenient measuring stick for determining the direct loss.

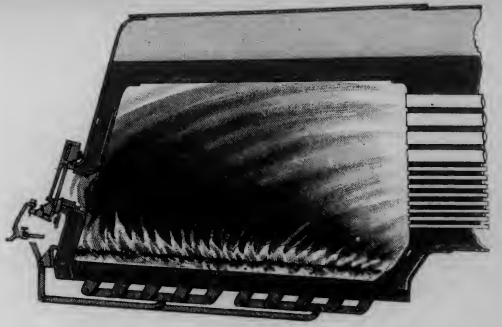
TESTING SAFETY VALVES.

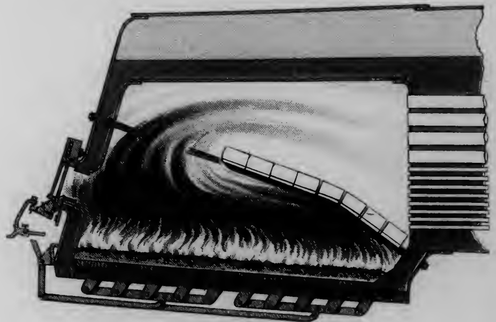
The Federal rules call for a quarterly test of pop or safety valves on all locomotives. The roundhouse man should endeavor to anticipate these tests so as to make them on dates when it is known that the locomotive will be ordered for service. This will save a part of the heat stored in the boiler, as well as the fuel remaining in the firebox after the test has been completed. It requires from 1,200 to 1,800 pounds of fuel to make this test, and consequently if made on date when the locomotive is not wanted this fuel is practically wasted.

STORED LOCOMOTIVES.

When locomotives are stored or housed with the fire in them the fire should not be cleaned but should be banked on top of the old fire, allowing the ash to remain on the grate to reduce the draft through the fire while the locomotive is stored.

Where locomotives are equipped with a brick arch the bank should be placed under the firedoor, and where not so equipped, against the back flue sheet. Then, just before the locomotive is required for service, the fire should be cleaned. Where it is not necessary to draw fires the stack should always be covered



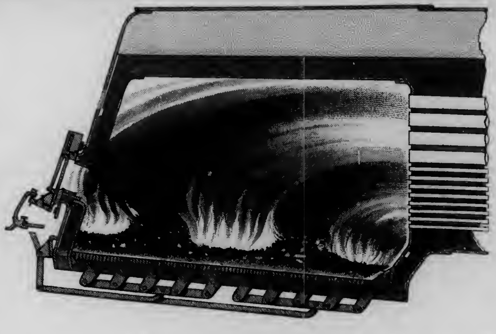


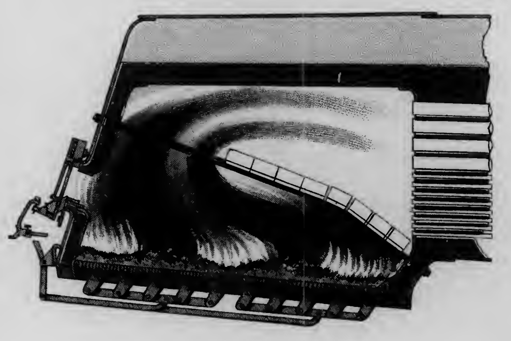
THE UNIFORM FIRE.

The condition here represented shows the admission of enough and not too much air. With the grates and draft apparatus in proper condition, a level and uniform firebed permits air to enter without undue obstruction over the entire grate surface and at the same time prevents cold air from entering through holes or thin spots.

With a light, level and bright fire most of the air supply enters the firebox through a uniform firebed. The firebed being uniform, without holes, clinkers, or banks, the air enters in many small streams equally distributed over the entire grate surface. Every part of the fuel bed and of the gases just above the fuel bed has its share of the uniformly distributed and finely divided air streams which are entering through the grates.

High and uniform firebox temperatures result from a proper air supply and a good mixture, and most of the coal and gases burn before they can escape from the firebox. High firebox temperatures insure the burning of combustible gases, which with lower firebox temperatures escape without giving up their heat.

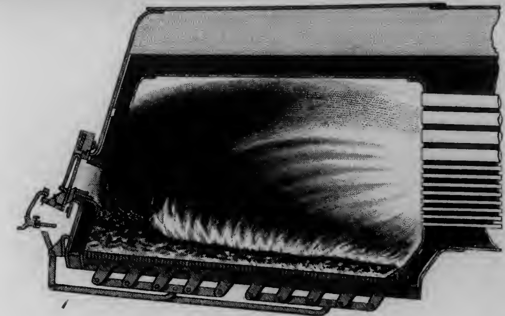


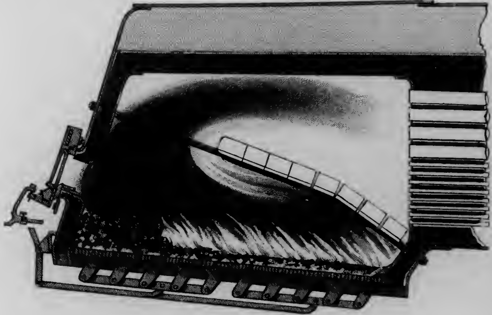


BANKS IN THE FIRE

The condition represented in the four figures above shows the results of both not enough air and of too much air. Banks may restrict the air supply to such an extent that there is not enough air to insure combustion. Even though large quantities of air may enter through the thinner parts of the fire or through the firedoor, the combustible gases arising from the banks may not receive a sufficient supply of air before they escape from the firebox. The firebox may be receiving too much air and still not burn the coal because of the poor mixing.

Above the thinner parts of the fire there may be more air than is needed to burn the fuel with which it comes in contact. This surplus air does not assist in the combustion process, but reduces the firebox temperature and carries off heat through the stack.

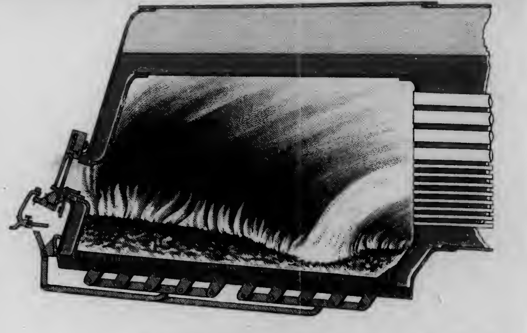


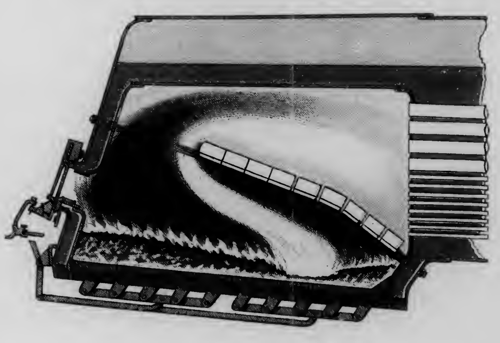


BANKS IN THE FIRE—Continued

Where the coal and gases are heaviest the incoming air supply is least, and neither the incoming air nor the gases arising from the fuel are sufficiently divided into numerous well-distributed small streams to permit easy and rapid mixing. Gases arising from the fuel bed reach the flues in a very short time and mixing must be rapid.

The banks of green coal and the smoky gas arising from them tend to cool the firebox as a whole. Some parts of the fire burn much more brightly than others and the temperature throughout the firebox is not uniform. Smoke and unburned gases result from this condition.





HOLES IN THE FIRE

When holes occur in the firebed the result is too much air in parts of the combustion chamber and not enough air in others.

Holes permit too much air to enter the firebox for the amount of coal which is being burned where the holes exist. The air coming through the hole is in a comparatively solid stream, and where this air comes through there is little fuel to burn. At points where there is fuel on the grate not enough air is coming through, and the opportunity for good mixing is lost.

The large volume of cold air coming through the hole cools that part of the firebox, and combustion in other parts of the firebox is retarded.

to retain the heat stored in the water and to prevent unequal expansion between flues and boiler which might result in leakage. A simple handy stack cover can be made as per figure 4. This can be placed over the stack from the floor and when not in use hung up on the roundhouse wall, one at each pit.

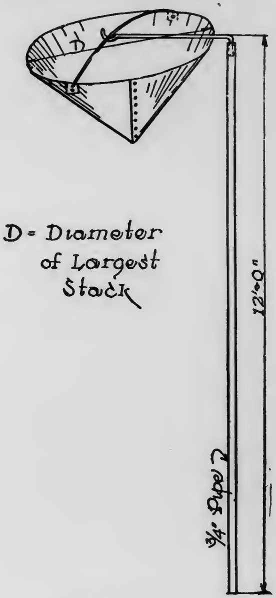


Fig. 4.—Stack cover.

Without maximum steam pressure a locomotive may be ever so well maintained but will be unable to handle the proper tonnage successfully, either from an operating or from an economical point of view.

The roundhouse supervision should exert every effort to eliminate defects on the locomotive which will in any way interfere with the free steaming qualities which are so necessary.

SAND PIPES.

The use of good sharp sand is essential in all classes of service to prevent fuel losses due to engines slipping, but the best of sand is useless unless delivered on the rail. This means that the sanding apparatus must be kept in good condition and that the sand pipes must be clamped so as to retain the correct alignment. The best method of keeping sand pipes in place and in line with the rail is to square the pipe where the clamp fits over it, then make the clamp square to fit the pipe.

DIRECT FUEL LOSSES.

In this class would come such losses as are visible when they occur, such as coal rolling off the tender on account of the tender being overloaded; coal rolling out of the gangway, due to defective or poor design of coal gates; lack of coal guards, etc.; coal falling through holes in deck of locomotive; coal jarred off when drifting or running fast due to excessive slack between engine and tender, etc. As the remedy for such defects is obvious, there is no need of calling attention to same except to say that no progressive roundhouse foreman who is interested in his work or in the success of his locomotive performance will allow such things to remain uncorrected at his terminal or on the locomotives under his care.

THE BRICK ARCH.

Few realize the importance, in fact the absolute necessity of the brick arch to secure the economical burning of fuel in the locomotive firebox, and to obtain perfect combustion it is absolutely necessary. Good combustion always emphasizes fuel economy, as it saves fuel and likewise saves labor on the part of the fireman, and it is only through the use of the arch that the highest temperatures in the firebox can be obtained, thereby creating another saving in the shape of higher superheat. This in turn means a smarter locomotive, and a smarter locomotive means a quicker trip. Furthermore, the arch means comparative freedom from honeycomb, less flue leakage, and last but not least, a marked reduction in spark losses, especially in stoker-fired locomotives, or when a grade of coal is used containing a high percentage of slack. Fewer sparks carried through the flues mean less stopped-up flues, and this in turn means a better steaming locomotive and less work for the roundhouse forces.

When locomotives are fitted with automatic stokers the arch should be extended well back. In hand-fired locomotives about six rows of brick are the usual limit, as a seven-course arch is apt to make it too hot at the door for comfort, but with a stoker-fired locomotive this feature need not be considered; therefore it can well be extended to an eight-course if the overhead (crown sheet) clearance will permit.

Speaking of the arch naturally reminds us of the arch tube. This in itself helps the steaming of the locomotive by improving the circulation; therefore keep the arch tubes clean. Turning a swab dipped in a mixture of crude oil and graphite through them when the boiler is washed will aid in preventing the adherence of scale and make the cleaning of them much easier.

THE SUPERHEATER.

The superheater consists of a separate coil of pipes located in each of the large smoke tubes, the ends of the coils being attached to the steam header located in the front end. When the throttle is opened steam flows through these coils and takes up additional heat from the hot gases passing through the smoke tubes. This increases the volume of the steam, makes it more lively, and the added heat prevents cylinder condensation. This condensation loss in the saturated steam locomotive amounts to about 30 per cent of the steam supplied to the cylinders. Therefore by reducing the condensation loss a higher cylinder effort is maintained and fuel is thereby saved. The superheater, however, requires as much care on the part of the roundhouse men and enginemen as any other part of the locomotive. The units should be tested frequently and kept free from leaks, and the smoke tubes should be kept absolutely clean. This is the duty of the roundhouse forces. The engineer should see that the water level is not carried so high that it will be drawn through the units with the steam, as this will result in making an auxiliary boiler of the superheater, thereby destroying the object aimed at in its application, but in addition to this the water carried over will deposit any scale-forming matter it may hold in suspension or solution on the inside of the superheater units, thereby coating them with an insulating material that will prevent the free passage of the heat contained in the gases into the steam moving through the units. It is this liming-up of superheater units through carrying the water too high or through foaming that causes the superheated locomotive to gradually lose its snap.

Figure 5 shows clearly what happened in actual service when the engineer opened the throttle so suddenly as to cause foaming. The temperature of the steam fell from 490 degrees to 360 degrees Fahrenheit, and at the end of 8 minutes the train was stalled, due to the excessive cylinder and valve friction encountered as a result of the alkaline water which was carried over with the steam washing away the film of oil ordinarily maintained on the walls of the valve chambers and the cylinders.

While there is a difference between carrying the water level too high and a foaming boiler, the results are quite the same; the only difference being that when the boiler begins to foam you can see the effect at once in dry valves, reduced speed, etc., while by carrying the water too high the evil effect is spread out over a greater distance and through a longer period of time. The bad effect is there, however, and always means more fuel and slower speed.

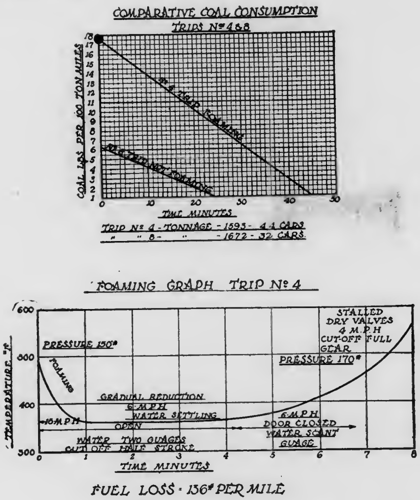


Fig. 5.—Graphs showing effect of foaming.

THE LOCOMOTIVE STOKER.

At present stokers consist of two general types, the overfeed, or scatter type, and the underfeed. In our limited space we can not go to the length of describing each type, but can only give a few general instructions common to all types.

As the stoker relieves the fireman of the greater part of his manual labor, he should at least take enough interest in the machine to see that it is in shape to work before starting—that is, he should on arrival at the locomotive see that the stoker is in operative condition by trying it; next, see that it is properly lubricated so it will stay in working order over the road; next, build up the fire by hand and see that it is ignited all over the grate surface. Don't try to build up the fire with the stoker, as the stoker may start a bank, and a bank with some certain grades of coal means a clinker, and a clinker means trouble. Don't start the stoker feeding until you have pulled out of the yard, and then *starve the fire*—that is, feed just as little coal as possible to maintain the desired pressure. Look into the firebox occasionally to see how the stoker is distributing the coal; it may save you hot work with the hook later on. Shut off the stoker when standing in sidings or drifting downhill. Keep up the fire with the scoop. Close the slides in the deck before reaching the terminal, but keep the stoker running so as to empty the conveyor trough. This will give the roundhouse men a chance to try the stoker and get it in shape for you for the next trip. Inspect it on arrival and report any defects found that develop on the trip. The engineer should know as much about a stoker and its care and operation as the fireman. It is as much a part of the locomotive as the injector or air pump, and an engineer that can not run it is not a fully qualified engineer.

Although the stoker may make it possible to keep ample steam pressure at all times, any failure on the part of the engineer to handle the locomotive skillfully will result in the same increase in the fuel and maintenance bills that are suffered when a hand-fired locomotive is abused.

Should the stoker stop operating on the road, don't keep on using steam until the pressure runs down, but stop, if possible, locate the trouble, and fix it. If you can not locate or repair the defect, give the fireman an opportunity to get the fire in shape so he can fire the engine to the terminal by hand. Do not give up the train because the stoker failed; and do not forget that the stoker was not designed to handle scrap iron, sulphur balls, or chunks of wood; therefore when you see foreign material in the coal throw out such before it enters the conveyor.

THE COAL PASSER.

This is a mechanical device to keep the coal within reach of the fireman. It may be either air or steam operated. If air is used, see that you have plenty of excess pressure before opening operating valve, as otherwise you may stick the train brakes. If steam is used, keep drain cocks open in freezing weather. With any type of coal passer an occasional application of oil where needed is necessary.

FIRING WITH ANTHRACITE COAL.

Anthracite and bituminous coal differ principally in their relative volatile combustible matter content. Lacking volatile gases, anthracite is a slow burning fuel and requires, generally speaking, a larger grate surface than does bituminous coal.

The most successful and economical method of firing anthracite depends almost entirely on the preparation of the fire. In cleaning an anthracite fire, all ashes and clinkers must be removed and a new bed of fire replaced over the entire grate surface, if we are to insure a prompt and positive burning or to ignite the fresh coal that is placed on the cleaned fire. This will give a uniform thickness to the fire, which can then be maintained by careful attention, but if the fire is cleaned in such a manner as to allow ashes or clinkers to remain in the fire after same has been cleaned, such will soon result in the formation of more ashes or dead spots. Anthracite coal after being placed on the fire should not be disturbed in any manner by a fire tool, even to remove clinkers or ashes, as it will not again burn level or develop the same rate of combustion over the grates. Having, as stated, but a small per cent of volatile matter, we must expect the heat value return from the solid or carbon which burns without long flame on the grates.

With this in mind, we must establish and maintain the fire bed so the necessary oxygen will enter and pass through the incandescent glowing mass, combining with same, thereby establishing perfect combustion. The perfect combustion of anthracite coal can be clearly determined by the eye, a clear-burning mass with a short flame; if the flame becomes diminished too much, however, the temperature and steam pressure will drop.

PREPARING THE FIRE FOR THE START.

In preparing the fire for the start (but not before it is known that the foundation or kindling fire is in good shape from corner to corner) it must be built up gradually to the proper depth for the service required. No fast rule can be made as to this depth, the size of the coal will, however, govern as well as the service. Fine sized coal requires a larger grate surface than the larger sized coal, but the larger sized coal requires a larger grate opening. With fine coal approaching buckwheat size, a fire of from 4 to 6 inches in thickness should be maintained; where lump size is used, a depth of from 12 to 15 inches in thickness will be necessary at times because of the openings that will exist between the large lumps as they lie on the grates. A fire of the last-mentioned thickness will quickly burn down to a lower level after the locomotive is put into service, and this lower level should then be maintained until the train approaches the terminal.

STARTING.

In starting, the fire should be in proper shape for the service which the locomotive is intended to perform, free from ashes and clinkers, burning all over, no dead spots. A sufficiently high steam pressure should be maintained for the air pumps and to start the train. It is important at this time to use the most careful judgment, otherwise a great waste of fuel will occur through the pop valve. In starting the train it is very important to guard against holes being torn in the fire by the heavy exhaust occasioned by the engine slipping, or by using the reverse lever at too long a stroke at the start. To avoid holes being torn in the fire the fireman should have the fire in such condition that the pressure can be held up with the firedoor held partly open. The engineer should also have the water level in the boiler just high enough so that when the effort in starting is over the injector can be applied.

When using anthracite coal no fuel should be placed on the fire at starting. This should be a case of "In time of peace prepare for war." After the effort of starting is over and the fire has reached a bright, glowing condition, begin firing as lightly as possible, to properly maintain the fire. Small quantities of coal fired at short intervals represent economical firing. In approaching a stop, or where a delay is anticipated, the fire should be burned down, and at the same time the engineer should increase the water level in the boiler and thereby avoid putting water in the boiler while standing.

The fire should at this time be covered over with fresh coal, unless a clean fire is required, thus bringing the fire to proper depth again. This will avoid the locomotive popping off, thereby wasting fuel. Coal so placed on the fire in this manner will prevent popping and also preserve the body of the fire under the coal, and in addition retard the entire burning action.

DESCENDING GRADES.

On approaching a descending grade, the water supply should be increased and the fire allowed to burn down after the throttle is shut off, in addition allowing the steam pressure to fall back below the popping point. Prepare the fire, if required, by cleaning same, or otherwise cover it over to preserve the fire and avoid popping.

MIXED ANTHRACITE AND BITUMINOUS COAL.

On certain locomotives, as well as in power plants, a mixture of anthracite and bituminous coal used in different proportions is consumed. While anthracite coal should be burned without being disturbed by a hook or fire tool, bituminous coal, however, often requires the use of the hook; this applies particularly where a large grate surface is available and a part of the grate surface is covered with a partially coked fire. This crust should be broken up so that every part of the grate surface will give up an equal amount of heat, thereby reducing the fuel consumption by effecting the highest state of combustion over the entire firebox instead of on but a portion of the grate surface.

The successful use of mixed coals depends in part on the relative quantities of the two fuels employed; as a general rule, the practices that govern the successful use of bituminous coal are equally applicable in the use of mixed coals.

OIL-BURNING LOCOMOTIVES.

The same general principles in so far as upkeep, handling, inspection, etc., that apply to the coal burner apply to the oil burner with this difference, however, that while it is hard to get enough air into the ashpan of the coal burner, it is quite easy to get too much air into the oil burner, and this applies especially to air leaks around the firebox, brickwork, and mud ring. Frequent inspection by turning on the blower and holding a lighted torch to these points should be made, and if leaks are found they should be corrected each trip, as air admitted as above takes a short circuit, goes directly into the lower flues, causes same to leak and to coat over with soot, arresting combustion at this point. Next to the proper alignment of the burner, the avoidance of air leaks is the greatest factor to be considered from a fuel-saving standpoint.

The burner should not be set so high as to cause the jet to strike the firedoor, nor so low as to allow the flame to drag on the bottom, and any obstructions in the shape of fallen brick etc.. in front of the burner should be removed at once.

HANDLING OIL.

Different grades of oil require different methods of handling However, all oil should be heated sufficiently to cause it to flow freely to the burner. While with many grades of oil the proper temperatures can be maintained with the closed heater, yet when using the heavy Mexican oils the open heater should be turned on strong at first, so as to stir up the oil, thereafter shut it off and maintain the proper temperature with the closed heater. No oil of whatever grade should, however, be heated to above a point where the back of the hand can not be pressed firmly against the tank without discomfort, for when oil is heated too hot, many valuable heat units escape in the form of gas.

OIL FIRING.

In firing with oil, the engineer and fireman must work together. Every time the engineer changes the throttle or reverse lever the fireman must regulate his firing valve to suit the changed requirement. From this it follows that the engineer should never start the engine until the fireman is at the firing valve, and should be careful not to slip the engine, as such is liable to put out the fire, and the fireman should be equally careful to not use too much steam at the atomizer. Steam will not burn, and a bright fire with just a tinge of blue smoke at the stack indicates good combustion. Black smoke and a red fire indicates waste. Enginemen should bear this one fact in mind regardless of whether they are handling oil or coal burners. *Any excess fuel used either on account of a defective locomotive or from poor handling on the part of the crew is a charge against them and not against the roundhouse.* Therefore exercise care while out on the road and report all fuel-wasting defects on arrival and so keep your record clear.

SUGGESTIONS TO LOCOMOTIVE ENGINEERS.

A locomotive fireman after having passed the necessary examinations assumes the duties of a locomotive engineer. Those who have passed through this apprenticeship and are placed in charge of a locomotive realize for the first time that for which they have striven. Your rating as an engineer depends on your ability to operate the locomotive in your charge in the most efficient and economical manner.

The suggestions in this book, if followed, will assist you to do this. The man who fails to follow same places himself in a position which may bring censure upon himself and others and seriously injures his reputation as a successful engineer.

When you are called to go out, endeavor to report at the enginehouse in plenty of time to check the register and bulletin boards and to thoroughly inspect the locomotive on which you are to make the trip. This applies to all engineers whether regularly assigned or otherwise. A close inspection before leaving terminal, particularly if work has been reported, and frequent inspections during the trip when conditions will permit, will prevent possible delays and engine failures that might otherwise occur.

Try the water glass cocks and gauge cocks and know that they are registering correctly. Know that all bearings are properly lubricated before leaving terminal, and thereby avoid having to stop later, on account of some bearing running hot to which you had not given proper attention. Try both injectors and know that they are in good condition. Start the lubricator about 10 to 15 minutes before leaving the terminal, in order that oil will reach valves and cylinders before any work is to be done.

In testing air brakes notice the fall of train line pressure while valve is on lap, and if this exceeds 5 to 7½ pounds per minute, notify car inspectors and be governed by the rules of the road by which you are employed.

It is well to note the condition of the fire unless you have an experienced fireman. Keep your fireman informed as to train movements in order that he may fire successfully.

In leaving the terminal, endeavor to work your engine as lightly as possible until the fireman has his fire in good condition. Work the engine at shortest cut-off consistent with the work required in order to get the benefit of the expansive use of the steam. Carry water at the proper height in order to get as dry steam as possible to cylinders. Water that is carried over into superheater or the cylinders of a saturated locomotive is reducing the effectiveness of your locomotive regardless of the steam pressure shown on the gauge. Overfeeding a boiler to a point where priming occurs on a superheated locomotive will reduce the temperature 80 or 100 degrees Fahrenheit.

Avoid rough handling in starting trains, as such may cause you drawbar trouble later on. If you are unfortunate and pull out a drawbar, study the conditions and try to avoid a reoccurence.

Avoid unnecessary stops for coal and water. Stop at points that will require the least effort to get the train away. It costs from 600 pounds to 1,500 pounds of coal to restore a train to speed, depending on the grade. Where conditions will permit, run coal dock in the direction in which coal is handled to coal dock.

Supervise the work of your fireman, giving him your help and the benefit of your experience. Team work is what counts. A locomotive is the equivalent of a large power plant; one, however, that is in motion when employed. Without a fixed foundation and compelled to carry its fuel and water supply with it, its management and operation under a continuous variety of conditions present problems that must be met instantly by the two men in charge. This situation calls for the best that is in the men in charge of the machine. Robust, conscientious, industrious effort will always bring to men of character a high measure of personal satisfaction and material reward. There is much met with that is irritating in every vocation. Keep good-natured and your work will be correspondingly light.

If your fireman does not employ the best practice, instruct him yourself and ask the road foreman or locomotive supervisor to have a friendly talk with him, setting him right.

Advise the fireman as to grades, shut-off points, the length of time it is probable the train will be held on side-track, etc., and explain to him your manner of handling the injector, so that he can anticipate your needs and fire accordingly.

Endeavor to work your engine at the shortest practicable cut-off at all times, so as to obtain full benefit of the expansive force of the steam.

Endeavor to feed the boiler uniformly, and do not allow the water level to rise so high that the effectiveness of the engine or the superheater will be destroyed.

By careful handling, good lubrication of the valves and cylinders can be maintained with a very small quantity of oil. Oil that is fed with steam sticks to the metal surfaces and will lubricate for a long time unless it is washed off by water or burned off by drifting. If a proper water level is maintained and attention is paid to the position of the throttle and the reverse lever when drifting, a few drops of oil will protect a large rubbing surface. If, however, in order to cover up errors in judgment too high a water level is carried when running, or if the boiler is overfilled when standing, water from the boiler with its scum and impurities will pass over with the steam and will scour the oil film from the cylinder and valve surfaces.

Whenever a high water level does occur, it will prove cheaper to use oil freely than to suffer the friction loss and fuel waste which result from dry valve seats and cylinder walls. Forethought will save both coal and oil; and engineers who make a good fuel performance generally make a good oil performance.

Avoid wasting steam at the pops. When conditions, such as emergency stops, make popping unavoidable, close your injector heater cocks and lightly blow steam back into the tank, thus heating the feed water. Injectors will lift water as warm as your hand (100 degrees); and feed water heated to this temperature saves about 4 per cent of the fuel and increases the locomotive's steaming capacity on hard pulls.

Careful judgment in handling the train brakes will save fuel. A moving train contains energy. Make the best use of this energy consistent with safety. If you lose it by unwise braking, it must be restored through the use of fuel, both for the train and the air pump.

Avoid slipping your engine. It tears the fire and wastes coal.

Do not use your cab lights or your headlight in the daytime.

SUGGESTIONS TO LOCOMOTIVE FIREMEN.

A man in accepting a position as a locomotive fireman should make a study of his work, mastering it in the same manner that he would any other trade or profession.

A skillful locomotive fireman becomes a skillful locomotive engineer, and thereby places himself in a position for further advancement.

A few minutes each day reading some authority on matters pertaining to your present duties, and those to which you aspire, will very materially assist you.

In firing a locomotive you are serving your apprenticeship as a prospective locomotive engineer and should consider the engineer for whom you are firing in the same position as the foreman of the shop in which you might be learning a trade, or the lawyer or doctor in whose office you might be studying the profession of law or medicine.

Harmony between the engineer and the fireman must exist in order to secure the best results. As the engineer is responsible for the performance of the locomotive while in his charge, so is the fireman responsible to the engineer for the manner in which he performs his duties. No one is better fitted to properly instruct the fireman than the engineer, as by his years of service he has learned by experience the manner in which these duties should be performed.

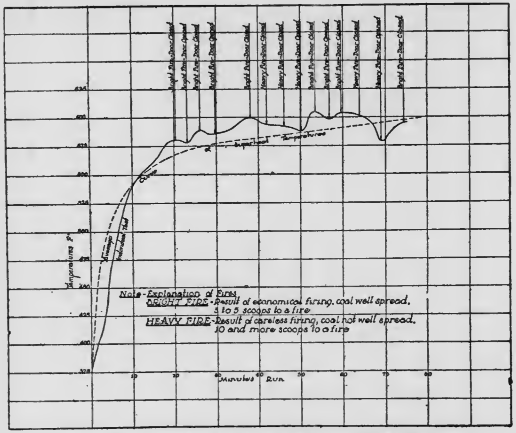


Fig. 6.—Diagram shows results of different methods of firing.

The duties of a locomotive fireman are varied, and merely keeping the locomotive up to the popping point is not an indication that he is a successful fireman. While proper steam pressure is essential, there are many other things which are just as important.

A good start goes far toward making for a successful trip. Get around early enough to try the grates, blower, firedoor, stoker, etc. See that you have all necessary supplies, then arrange your fire so you will not have to work with it when you should be looking for signals.

Before leaving, have your fire built up so that the heavy exhaust due to starting the train will not tear holes in it; thereafter fire as lightly as possible. Avoid "slugging" the fire regardless of whether the locomotive is hand or stoker fired—this will save you work later on. The diagram, figure 6, shows the results obtained from different methods of firing. Note particularly the drop in steam temperature after a heavy fire. Each drop in temperature means a waste of fuel and time lost in going over the road. Do not try to carry the steam pressure at the popping point, but within about 5 pounds of same, this in order to avoid opening the door to prevent popping in case of an unexpected stop. Every time the pops open fuel is wasted.

Worry wears more than work. The fireman will worry if he can not keep steam. Try cracking the coal, firing light and often, closing the door between scoops. Keep the deck clean. This looks better, saves coal, and may save you a sprained ankle. Wet the coal just enough to keep down the dust. Too much water on the coal retards combustion. Water will not burn.

Avoid the excessive shaking of grates, but keep the fire down in order that sufficient air can pass through the fire. By firing light and keeping the fire shaken down so that the firebox will not fill up with ashes, you will insure the absence of black smoke, which is one indication of perfect combustion. An excessive amount of black smoke escaping from the stack is an indication of improper firing and should be avoided. Keep the fire free from banks, as the brighter the fire, the more heat is produced.

Do not use the rake unless it is absolutely necessary, and then only to remove clinkers or to remove a bank. Learn the profile of the road so that you can have your fire in condition to do the work required. When engine is not using steam, and water is being supplied to the boiler, have your fire in such condition that the water entering the boiler will not reduce the temperature of the firebox and sheets to a degree that would cause them to leak.

The overloading of tanks with coal is a serious proposition. You not only waste the coal that falls off, but employees and passengers may be seriously injured. A few minutes of your time taken in leveling the coal down will avoid this. Think about it. Is it worth your time to save some one from possible injury? At the end of your run, when the locomotive is placed on the receiving track, have your fire in such a condition that it can be either dumped or maintained as conditions demand, and see that there is sufficient water in the boiler to keep it safe until the hostler takes charge. Notify the engineer of all defects that should be corrected, that he may report same.

Close the firedoor after each scoopful of coal is fired.

Do not slug the fire. Three or four scoops to a fire, even with the largest locomotives, has been proved practicable and gives the most economical results.

Do not shake the grates except when absolutely necessary—and then shake them gently. They should never be shaken while the engine is working hard; the high draft will then carry ash up into the tubes and superheater flues and clog them.

Do not rake the fire, unless it be to fill up a hole or to break down a bank.

When your engine is running with a drifting throttle, fire only enough coal to keep the fire in good condition.

If large lumps of coal reach your tender, break them down before firing them.

Use the blower as lightly as possible, and no longer than is necessary.

When entering a terminal let your fire burn down to the proper level; but do not starve it to the point where, in order to get a boilerful of water, it will become necessary to rebuild it just before the locomotive goes on the cinder pit.

Do not use the injector when there is little or no fire in the locomotive. To do so starts the flues and side sheets leaking.

Keep your deck clean. A well-swept deck with the coal in the tender sprinkled, but not flooded, helps save coal and increases your comfort.

Do not permit coal to fall off the gangway. This is not only wasteful but dangerous.

Study the methods of good firing. Talk about them with other firemen. Try to improve your own practice.

On oil-burning locomotives, sand the flues frequently; save oil by avoiding black smoke.

Whether using coal or oil, persistent black smoke indicates poor firing. Try at all times to avoid it, but especially in cities, where it causes not only fuel waste, but discomfort and damage.

The colored illustrations facing page 16 clearly show the results of proper and improper firing.

SUGGESTIONS TO ENGINEHOUSE OFFICIALS.

Have coal shoveled ahead on tenders at terminals remote from the mines, and put on no more coal at such points than is necessary to take the train back to the terminal nearest the mines.

Insist that tenders be not so overloaded as to spill coal. Have them trimmed before leaving the chute, so that surplus coal may be picked up.

Do not permit locomotives to be held under steam unnecessarily. If they must be held, bank the fires—if they are to be held for 24 hours, remove the fires.

Whenever locomotives stand under steam, cover the stacks. A simple sheet-iron or wooden cover suffices, and saves heat and coal. If used when fires are dumped, such a stack cover saves heat and reduces boiler maintenance.

Do not allow a locomotive to leave the terminal unless its fire is in proper condition.

Unless absolutely necessary, do not allow fresh coal to be placed in the firebox while the locomotive is held for its fire to be knocked.

To avoid delay at leaving time, have tools and supplies placed on the locomotive before the crew reports.

Maintain firedoor openers so that they will operate properly.

Arrange firedoors not equipped with automatic openers so they can be easily swung open and will remain latched open in rounding curves; and so they can be easily swung shut after firing each scoop of coal.

Brick arches must be maintained.

Remove injectors which are too large. Replace them with those of proper capacity.

When locomotive fires are cleaned, have a competent inspector enter the firebox. He should assure himself that the grates are thoroughly clean; that there are no broken grate fingers or excessive openings; that the grate is level when the grate-lever keepers are in place and locked; and that the arches are clean and in repair. He should also see that the flues are clean and free from leaks, particularly the superheater flues. Superheater flues when clogged with soot and cinders are useless.

See that all coal-burning locomotives have a total ashpan air opening equal to at least 14 per cent of the grate area.

Maintain boilers up to their highest efficiency; wash them when necessary and have the flues bored and blown out every trip. Give special attention to the superheater flues.

Eliminate front-end air leaks.

Do not allow locomotives to run with mud-ring leaks. This leakage represents a considerable waste of fuel.

Make a special inspection of all locomotives to see that the exhaust nozzles are opened up to the largest area consistent with proper steaming. Keep a nozzle record of all locomotives, showing the class, size, date of cleaning, and date of nozzle changes.

Holes in the cab decking, defective aprons, and lost motion in the tender connections all lead to direct coal losses.

Make certain that steam pipes and superheaters are tested at frequent intervals. Cold-water tests should not, however, be made when the parts are hot.

See that cylinder and valve rings are maintained so that they do not blow; and keep the valves squared up on all locomotives.

On oil-burning locomotives maintain all piping, valves, and operating fittings in good condition. Keep the burner clean and in proper alignment, making periodical inspections of burners to determine if defective. Pans must be maintained in good condition and rigidly secured to avoid air leaks at sides and front behind brickwork. Inspection should be made each trip to insure brickwork being in good condition and all carbon and sand removed. Keep air openings free from slag and carbon accumulations.

The flues in an oil-burning boiler require the same attention as a coal-burner. Dampers should be maintained over all air openings, and must be easy to operate.

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